DOCUMENT RESUME

ED 070 597 SE 014 898

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TITLE	Reactions of Atoms and Molecules, Science (Experimental): 5316.02.
INSTITUTION	Dade County Public Schools, Miami, Fla.
PUB DATE	71
NOTE	16p.; An Authorized Course of Instruction for the Quinmester Program
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Atomic Structure; Behavioral Objectives; *Chemistry; *Curriculum; Instructional Materials; *Objectives; Science Education; *Secondary School Science; *Teaching Guides
IDENTIFIERS	*Quinmester Program

ABSTRACT

This course, intended for first year chemistry students, introduces the mole concept through the use of experimentation. Performance objectives are specified and a course outline is given. A total of 42 experiments from eight texts, sources for eight demonstrations, and suggestions for accompanying film strips and film loops are included. Lists of report topics, projects, sample problems, and discussion questions are provided; speakers and field trips in the Dade County area are suggested. Bibliographies of four state adopted texts and 18 other references are included. For other documents in this series, see ED 062 175 through ED 062 180. (DT)

AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

REACTIONS OF ATOMS AND MOLECULES

5316.02

SCIENCE
(Experimental)

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

REACTIONS OF ATOMS AND MOLECULES

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SCIENCE
(Experimental)

Written by: Chemistry Advisory Committee
First Revision by Jacquelin F. Buffaloe
DIVISION OF INSTRUCTION
Dade County Public Schools
Miami, Fla.
1971

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Published by the Dade County School Board

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REACTIONS OF ATOMS AND MOLECULES

COURSE DESCRIPTION:

Reactions of Atoms and Molecules introduces the mole concept through the use of experimentation. Information from these experiments will allow the student to write formulas and balanced equations and to solve simple stoichiometric problems. The laboratory investigations should guide the students into a study of bonding and molecular structure. This course is adaptable for all first year chemistry students who are successful in Scientific Mathematics and Introduction to Chemistry.

ENROLLMENT GUIDELINES:

The course is intended for all first year chemistry students who have been successful in Introduction to Chemistry and Scientific Mathematics or who show their readiness through an acceptable score on a suitable test.

STATE ADOPTED TEXTS

1. Choppin and Jaffee. Chemistry: Science of Matter, Energy and Change. Morristown, New Jersey: Silver Burdett Co., 1965.

2. Greenstone, Sutman, and Hollingworth. Concepts in Chemistry. New York: Harcourt Brace and World, 1966.

3. Metcalfe, Williams, and Castka. Modern Chemistry. New York: Holt, Rinehart, and Winston, Inc., 1966.

4. O'Connor, Davis, Haenisch, McNab, and McClellan. Chemistry: Experiments and Principles. Atlanta: Raytheon Education Company, 1968.

PERFORMANCE OBJECTIVES

1. Given a periodic table and a formula the student will demonstrate his knowledge of the mole concept by calculating:

   (1) the gram atomic and gram molecular masses
   (2) the mass of one atom or molecule
   (3) the mass of a given number of moles
   (4) the number of moles when a mass is given

2. Given an equation, the student will interpret its meaning in terms of atoms, molecules, moles, gas volume, and mass.

3. Given the chemical names of the reactants and products in a chemical reaction, the student will

   (1) write the formulas for the chemicals
   (2) write the balanced equation using the inspection method
   (3) demonstrate his knowledge of the mole concept by using the relationships in the equation to solve weight-weight, weight-gas volume, and gas volume-gas volume problems.

4. Given a periodic table the student will predict the types of bonds (covalent or electrovalent) formed when atoms combine.

5. Given a periodic table, the student will predict the shape of molecules in which bonding involves s and p electrons. (OMIT FOR NURSING CHEMISTRY.)

COURSE OUTLINE

I. Mole Concept

A. Gram molecular and gram atomic masses

B. Weight of one atom or molecule

C. Weight of mass of a given number of moles of atoms

D. Number of moles when a mass and formula are given
(Problems should be simple for Nursing Chemistry students)

II. Writing, Balancing, and Using Equations

A. Writing formulas and naming compounds

B. Writing equations

C. Balancing equations using inspection method

D. Problems to solve: wt.-wt.; wt.-gas volume; gas volume-gas volume
(Problems for Nursing Chemistry students should use simple arithmetic.)

III. Bonding

A. Types of bonds

B. Requirements for formation of bonds

IV. Molecular Structure (Omit for Nursing Chemistry)

A. Basic types of structure (shape)

B. How to predict shape of molecules

EXPERIMENTS

Castka, Metcalfe, and Williams. Exercises and Experiments in Chemistry. New York: Holt, Rinehart, and Winston, 1966.

1. Exercises and Experiments in Chemistry (pp. 153-145)
2. Mass Relations in a Chemical Change (pp. 147-148)
3. Types of Chemical Reactions (pp. 149-152)
4. Replacement of Hydrogen by a Metal (pp. 155-56)
5. Molar Volume of a Gas (pp. 157-158)
6. Molecular Weight of a Gas (pp. 159-160)

Davis, MacNab, Haenisch, McClellan, O'Connor. Laboratory Manural for Chemistry: Experiments and Principles. Atlanta: Raytheon, 1968.

7. The Masses of Equal Volumes of Gases (pp. 8-11)
8. Copper - Silver Nitrate Reaction (pp. 17-20)
9. Conservation of Mass During Chemical Change (pp. 21-25)
10. The Reaction of Magnesium with Hydrochloric Acid (pp. 32-37)
11. Formula of a Precipitate (pp. 46-49)

Ellis and Toon. Laboratory Experiments for Foundations of Chemistry. New York: Holt, Rinehart and Winston, 1968.

12. Mole Concept (pp. 48-51)
13. The Properties of Some Representative Elements (pp. 38-42)
14. The Significance and Use of the Periodic Table (pp. 88-93)
15. Chemical Bonding (pp. 94-97)
16. Bonding Capacities of Atoms and Directional Character of Hybrid Bonds (pp. 98-101)

Ferguson, Schmuckler, Siegelman. Investigating Matter, Energy and Change. Morristown, New Jersey: Silver Burdett Co., 1966.

17. The Mole and the Molar Volume (pp. 53-56)
18. Mole Ratio and the Chemical Reaction I (pp. 63-68)
19. The Formula of a Compound (pp. 57-61)

Gellner, Lauren. Experimental Chemistry and Workbook. New York: Amsco Publications, 1968.

20. Determination of Atomic Weight Using Specific Heat Data (pp. 71-74)
21. Determination of the Percentage of Water in a Hydrate (pp. 41-42)
22. Electrical Conductivity of Solutions of Compounds (pp. 43-46)
23. Electrolysis (pp. 131-134)
24. Relative Weights of Gases (pp. 55-58)
25. Stoichiometry and Chemical Change (pp. 59-64)

Greenstone. Concepts in Chemistry - Laboratory Manual. Atlanta: Harcourt, Brace and World, 1966.

26. Separating Oxygen From an Oxide (pp. 24-25)

27. Determining the Emperical Formula of a Compound (pp. 38-40)
28. Determining the Molecular Weight of a Gas (pp. 41-43)
29. Molecular Weight by the Vapor Density Method (pp. 44-45)

Pimentel, George C. ed. Chemistry: an Experimental Science Laboratory Manual. San Francisco: W. H. Freeman and Co., 1963.

30. The Weights of Equal Volumes of Gases (pp. 14-18)
31. The Behavior of Solid Copper Immersed in a Water Solution of the Compound Silver Nitrate (pp. 19-21)
32. Mass Relationships Accompanying Chemical Changes (pp. 22-26)
33. A Quantitative Investigation of the Reaction of a Metal with Hydrochloric Acid (pp. 26-30)
34. An Investigation of the Reacting Volumes of Two Solutions of Known Concentration (pp. 31-33)
35. Reactions Between Ions in Aqueous Solution (pp 34-35)

Smith, William T. Jr. Laboratory Manual for College Chemistry. New York: Harper and Row, Publishers, 1966.

36. Percentage Composition of a Compound: Relative Atomic Weights (pp. 17-20)
37. Changes; Substances (pp. 25-28)
38. Molecular Weight of Carbon Dioxide (pp. 55-60)
39. Percentage Composition of Copper Oxide (pp. 65-68)
40. Molar Gas Volume (pp. 69-72)
41. Formula of a Hydrate (pp. 77-80)
42. Combining Weight of a Metal (pp. 123-126)

DEMONSTRATIONS

Alyea and Dutton. Tested Demonstrations in Chemistry. Easton, Penn: Division of Chemical Education of the American Chemical Society, 1962.

1. Determination of Equivalent and Atomic Weights (pp. 71-72)
2. Determination of Atomic and Molecular Weights (pp. 72-74)
3. Water - Synthesis, Composition of Water (pp. 59-60)
4. Law of Conservation of Mass (p. 54)

Ellis and Toon. Laboratory Experiments for Foundations of Chemistry. New York: Holt, Rinehart and Winston, Inc., 1968.

5. Electron Transitions in Atoms (pp. 8-83)

Fergerson, Schmuckler, and Siegelman. Investigating Matter, Energy, and Change. Morristown, New Jersey: Silver Burdett Co., 1966.

6. Mole Ratios and Chemical Reactions III (pp. 193-198)

DADE COUNTY 16mm FILMS

1. Chemical Bonding
   AV# 1-10814, 20' C
2. Chemical Reactions
   AV# 1-12975, 18' BW
3. Determination of Atomic Weight
   AV# 1-10925, 19' C
4. Gases and How They Combine
   AV# 1-10844, 22' C
5. Laws of Conservation of Energy and Matter
   AV# 1-01753, 8' C
6. Ionization Energy
   AV# 1-10864, 22' C
7. Shapes and Polarities of Molecules
   AV# 1-10895, 18' C

Educators' Guide to Free Films - 29th Edition, 1969.

8. Metal Crystals in Action 30' C (American Soc. for Metals)

FILM STRIPS

Available from Encyclopedia Britannica Films From Series 10800 Experiments in Chemistry.

1. Determination of a Formula
2. Molar Volume of a Gas

FILM LOOPS

Available from Ealing

1.	Definite Proportions: Electrolysis of Water	84-0165/1	$22.95
2.	Combining Volumes: Synthesis of Water	84-0177/1	22.95
3.	Conservation of Mass	80-3254/1	22.95
4.	Mass of an Atom	80-3353/1	22.95

Transparency masters are available from the multi-media center at Lindsey Hopkins Building.

REPORTS

1. Methods of determining the atomic weight
2. Methods of determining the molecular weight of volatile materials
3. Methods of determining the molecular weight of non-volatile, non-electrolytes
4. Determination of the number of atoms in a mole
5. Creation of a new unit to replace the mole and an explanation of the application of the new unit
6. Correlation of the bonding trends and the Periodic Table
7. Covalent vs. electrovalent bonded compounds: comparison and explanation of properties of compounds with the types of bonds.
8. Historical development of the mole concept
9. History of Avogadro's Hypothesis
10. Describe the five basic shapes of molecules and explain how to predict the shape of molecules which have bonding involving s and p electrons

PROJECTS

1. Determine the weight of one mole of a variety of chemicals including both elements and compounds
2. By experimentation or through literary research compare and contrast the properties of
   (a) ionic compounds
   (b) covalent compounds
   (c) polar covalent compounds
3. Devise a method or methods of determining the formula of a chemical.
4. Devise a method for determining the molar relationship of gases in a reaction, then test the method.
5. Devise tests which could be conducted to determine the type of bonding in a compound.
6. Determine the molar volume of several gases, solids, and liquids. What factors determine the volume?
7. Use the slide rule in various types of calculations.
8. Construct a set of atomic models which can be used to form molecules.
9. Construct models of the five basic molecular structures.

SAMPLE PROBLEMS

1. Determine the volume occupied by 4.0 grams of oxygen at standard conditions. What portion of a mole is this weight?
2. Determine the approximate molecular weight of a gas if 560 ml weighs 1.55 grams at STP.
3. Determine the molecular weight of (a) sulfuric acid, H_2SO_4, (b) ethyl alcohol, C_2H_5OH.
4. (a) How many grams of H_2S are contained in 0.400 mole of H_2S?
   (b) How many gram-atoms of H and S are contained in 0.400 moles of H_2S?
5. How many moles of phosphorus are contained in 92.94 grams of phosphorus if the formula of the molecule is P_4?
6. How many moles are represented by 9.54 grams of SO_2?
7. What is the weight of one molecule of SO_2?
8. What is the weight of one atom of Cu?
9. Given the following equation, calculate the items described below:

   $Ca_3(PO_4)_3 + 3\ SiO_2 + 5\ C \longrightarrow 3\ CaSiO_3 + 5\ CO\ (g) + 2P$

   (a) number of gram-atoms of phosphorus formed for each mole of $Ca_3(PO_4)_2$ used
   (b) number of grams of phosphorus formed for each mole of calcium phosphate used
   (c) number of liters of CO measured at STP that would be produced if 100 grams of SiO_2 were used
   (d) number of grams of phosphorus produced for each 100 grams of silicon dioxide used

10. Write the equation for the production of HCl from hydrogen gas and chlorine gas. Use this equation to calculate the quantities below.
    (a) If 100 liters of hydrogen gas is used, how many liters of hydrogen chloride will be produced? Consider constant conditions.
    (b) If 100 liters of hydrogen gas and 78.3 liters of chlorine gas are mixed at STP, how many grams of HCl will be produced?

DISCUSSION QUESTIONS

1. Why should chemistry students study the mole concept.
2. What type of calculations can be made if one understands the mole concept?
3. Industrial processes are conducted in terms of tons. Does this contradict the necessity to learn about moles and gram-molecular weights? Explain.
4. What terms can be used to read an equation? There are many. Do the conditions or states of matter control the use of certain types of units? Explain.
5. How did scientists decide that 32 grams of oxygen was the weight of one mole?
6. What do you have to know before you can write an equation for a reaction? If you are to do no experimentation, where would you expect to find such information?
7. What type of rules would you need in order to have a uniform system for naming chemicals?
8. What type of information is given by an equation?
9. How is an equation like a recipe? How is it different?
10. What factors must you consider when predicting the type of bond that will form between two atoms?
11. How does the structure of the atom affect the bond type that results between two atoms?
12. What factors must be considered when predicting the shape of a molecule?
13. How does the structure of a molecule contribute to its chance of being polar?
14. What properties does the ionic bond give a compound? covalent bond?
15. How could you distinguish between compounds with covalent and with ionic bonding?

SPEAKERS AND FIELD TRIPS

Such activities at this part of a chemistry course should create interest, inform students of career opportunities, and allow the student to see chemists at work. Below are listed organizations and businesses which will, by appointment, provide tours of their facilities or send speakers to the school.

1. Dade County Medical Association
2. East Coast District Dental Society
3. South Florida Veterinary Medical Association
4. Southeast Florida Pharmaceutical Association
5. City of Miami Water Plants
6. Dade County Air and Water Pollution Control
7. American Society for Metals
8. American Institute of Industrial Engineers
9. Dade County Department of Public Health
10. University of Miami School of Medicine
11. Dade Reagents

Instructors should check the booklet of Visiting Scientists which is sent to the school each year.

REFERENCES

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2. Barrow, Gordon M., et al. Chemical Bonding from Understanding Chemistry. New York: W. A. Benjamin Inc., 1967.
3. Barrow, Gordon M., et al. Chemical Quantities: Gram-atom and Moles from Understanding Chemistry. New York: W. A. Benjamin Inc., 1967.
4. Mahan, Bruce H. College Chemistry. Reading, Mass.: Addison and Wesley Publishing Co., 1969.
5. Mariella, Raymond. Chemistry of Life Processes. New York: Harcourt Brace and World, 1968.
6. Pauling, Linus. The Nature of the Chemical Bond. Ithaca, New York: Cornell University Press, 1960.
7. Pimentel, George C. ed. Chemistry: an Experimental Science. San Francisco: W. H. Freeman and Co., 1963.
8. Plane, Robert A. and Sienko, Michell J. Chemistry (2nd ed). New York: McGraw-Hill, 1961.
9. Ryschkewitsch, George E. Chemical Bonding and the Geometry of Molecules. New York: Reinhold Publishing Corp., 1963.
10. Schaum, Daniel. Theory and Problems for Students of College Chemistry. New York: Schaum Publishing Co., 1956.
11. Sebera, Donald K. Electronic Structure and Chemical Bonding. New York. Blaisdell Publishing Co., 1964.
12. Sienko, M. J. Stoichiometry and Structure, from Freshman Chemistry Problems and How to Solve Them. New York: W. A. Benjamin, 1964.
13. Sisler, Harry H. Electronic Structure Properties and the Periodic Law. New York: Reinhold Publishing Corp., 1965.
14. Smith, William T. and Wood, Jesse H. Laboratory Manual for College Chemistry. New York: Harper and Row Publishers, 1966.
15. White, Emil H. Chemical Background for Biological Sciences. Englewood Cliffs, New Jersey: Prentice Hall Inc., 1964.
16. White, Harvey E. Modern College Physics. Princeton, New Jersey: D. van Nostrand Co., Inc., 1962.
17. Vaczek, Louis. The Enjoyment of Chemistry. New York: Viking Press, 1964.
18. Vanderwerf, Calvin. Acids, Bases, and the Chemistry of the Covalent Bond. New York: Reinhold Publishing Corp., 1962.

MASTER SHEET - REACTIONS OF ATOMS AND MOLECULES

Objectives	Experiments	Student Text	General Reference	Films	Film Loops	Film Strips	Demonstrations
1	10, 12, 14, 17, 18, 20, 24, 28, 29, 36, 38, 42	4 pp. 25-40 1 pp. 76-95 2 pp. 176-177 133 122-124 3 pp. 104-112	1 pp. 9-10, 13-14 3 All 8 pp. 20-30 10 pp. 21-52 12 pp. 128-143, 153-174 15 pp. 5-7 16 p. 169 17 pp. 82-88 7 pp. 32-34	3	4		1, 2
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